

The University of Chicago

TECHNOLOGY AND THE FRENCH
GLASS INDUSTRY, 1640-1740

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
SOCIAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF ECONOMICS

1940

By
WARREN C. SCOVILLE

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*Technology and the French Glass Industry, 1640-1740*¹

I

INDUSTRIAL expansion depends upon the state of the industrial arts. If we are to explain the rise of "modern industry"² we must know precisely what the technological developments were in particular industries during those periods that are recognized as having been extremely important in the development of modern industrial techniques. This study, therefore, deals with the growth, structure, and technology of the French glass industry during a critical period (1640-1740).³

It will be well to understand at the outset the state of technology attained by 1640 because glass making for commercial purposes already required several men to work together at a common furnace.⁴ In Southern France, where most glass shops made bottles, drinking cups, and similar ordinary objects of common green glass, the typical furnace was circular

¹ A traveling fellowship from the University of Chicago in 1936-1937 made possible the acquisition of data used in this study.

² Perhaps the most important single feature of "modern industry" is the production of commodities on a very large scale by privately owned and privately operated plants using expensive, complicated machinery and employing large numbers of wage earners working together under their employer's roof.

³ The industry can definitely be divided into at least five branches: (1) plate, mirror, and optical glass, (2) white or crystal glass, (3) common green glass, (4) bottle glass, and (5) window glass.

⁴ In my description of the methods followed in French glass production I have relied to a great extent on numerous illustrations found in Vols. IV and X of the *Recueil de planches sur les sciences, les arts libéraux et les arts mécaniques, avec leur explication* (Diderot and D'Alembert, eds.; Paris, 1765, 1772) and in Vols. III, V, and VII of the *Recueil de planches de l'encyclopédie par ordre de matières* (Panckoucke, publisher; Paris, 1784, 1787, 1789) and on the excellent articles entitled "Glacerie, ou l'art de fabriquer les glaces" and "Art de la verrerie" in Vols. III and VIII, respectively, of the *Encyclopédie méthodique: arts et métiers mécaniques* (Panckoucke, publisher; Paris, 1784, 1791). Although these works were published during the latter half of the eighteenth century, they are extremely helpful to any one interested in the technology of glass production during the century following 1640. The archives of the Saint-Gobain Plate Glass and Chemical Company in Paris contained (in 1937) abundant data on the techniques used in the production of all kinds of glass in France during the seventeenth and eighteenth centuries. Several published works also proved useful: Bosc d'Antic, *Oeuvres, contenant plusieurs mémoires sur l'art de la verrerie* . . . (Paris, 1780); Haudicquer de Blancourt, *L'Art de la verrerie* (new ed.; Paris, 1718); C. Loysel, *Essai sur l'art de la verrerie* (Paris, an VIII); Néri, Merret, and Kunckel, *Art de la verrerie* (Laurent Durand, trans.; Paris, 1752); Savary des Bruslons, *Dictionnaire universel de commerce* (Paris, 1723); and Bénétou de Perrin, "Dissertation sur la verrerie," *Mémoires pour l'histoire des sciences & des beaux arts* (commonly called *Journal de Trémoux*) (Trémoux, octobre 1733).

at its base and outwardly resembled a gigantic beehive. Batch⁵ filling five or six crucibles was melted in one compartment, and pieces of blown glassware were gradually cooled in an annealing compartment at the apex of the same furnace. Such a furnace was considerably smaller than the square or rectangular one usually found in those shops of Normandy making window glass. Auxiliary ovens for calcining raw materials and for tempering crucibles were built at the four corners of the Norman furnace and were heated by means of small flues in the walls of the melting furnace. The fire was not built directly on the ground, as was done in the beehive furnace, but on a grate extending the length of the furnace with a rather deep ash bin and a draft underneath. The German furnace (*four à l'Allemagne*) was employed before 1640 in certain French shops, especially in those making common and white glass in Northeastern France. In only one respect did this furnace differ from the Norman: its grate was opened at both ends rather than at one. Consequently, the fireman, by feeding the fire through both openings and by regulating the two drafts, could whip up a hotter blaze than was possible in the Norman furnace.

All of these types, the beehive, the Norman, and the German, had to be carefully made of argil bricks lest they collapse while the batch was being melted or while the molten glass was being blown.⁶ During the seventeenth and eighteenth centuries most Continental glass was made of sand, potash or soda, cullet, and, occasionally, lime. Manganese or cobalt were sometimes used to modify the natural greenish color of such glass.⁷ The cheapest green glass and the most transparent crystal or plate glass usually were made of the same basic materials mixed in different proportions. After the sand and cullet had been washed and mixed with the other materials, the batch was heated and calcined in special ovens. Then it was melted and refined in open crucibles placed in the main furnace. By dipping the end of their pipe into one of these crucibles the workers got enough molten glass to make a bottle, demijohn, drinking cup, goblet, or whatever their specialty may have been. French glass blowers commonly used wooden or copper molds to shape only the base of bottles and jugs; other objects were fashioned by hand. In Normandy, for example, window glass was made by blowing a large bubble and then pricking and

⁵ The mixture of unmelted materials from which glass was made.

⁶ Archives Nationales, F¹². 1489A; Y. 14124; Archives Départementales de la Gironde, C. 310, 1594; Archives Départementales de la Seine-Inférieure, E. Famille du Vaillant Desmarêts.

⁷ Archives Nationales, F¹². 1489B; Archives de la Compagnie de Saint-Gobain, *Porte-feuille des arrêts et mémoires*; *Encyclopédie méthodique: arts et métiers mécaniques*, III, 155; VIII, 451, 471-472, 478, 487, 499-501; Haudicquer de Blancourt.

opening it out into a flat disk. In Northeastern France, where windowpanes were produced in the German or Bohemian manner,⁸ workers blew long cylinders which they slit and flattened out in specially built annealing ovens.

None of these techniques was new by 1640. Both the German furnace and the German method of blowing window glass had been used by Lorrainers before the opening of the seventeenth century.⁹ Furthermore, Italian methods used in making artistic and delicate objects of crystal glass had been introduced into numerous French provinces during the sixteenth and early decades of the seventeenth century by Altarian artisans, who had been encouraged by their duke to emigrate, or by Venetians, who had left their native furnaces in defiance of certain danger and possible death.¹⁰ Before 1640 several French shops had become so successful in imitating Venetian crystal that their products were scarcely distinguishable.¹¹ A producer at Antwerp in Belgium complained around 1607 that various people were violating his exclusive right to make and sell, within a limited area around his shop, all crystal ware other than true Venetian. "Certain merchants," he claimed, "instead of importing their glasses from Venice, draw them . . . from more neighboring places where one counterfeits Venetian glasses so well that glass makers themselves are able to discern the difference only with great difficulty; [and] the shops built at Mézières and Liège sell their wares as products from Venice, thereby deceiving the court and the people to the great prejudice of the State."¹²

⁸ These methods were practically identical. Windowpanes à la Bohême (or en table) were slightly thicker than those à l'Allemagne (or en manchon) and were always gradually cooled in annealing ovens before they were cut and flattened out.

⁹ See J. Beaupré, *Les Gentilshommes verriers, ou recherches sur l'industrie et les privilèges des verriers dans l'ancienne Lorraine aux XVe, XVIe et XVIIe siècles* (2d ed.; Nancy, 1846); Henri Lepage, "Recherches sur l'industrie en Lorraine et principalement dans le département de la Meurthe (verreries, papeteries, cartes à jouer, mines)," *Mém. de la soc. des sciences, lettres et arts de Nancy*, XXVI (Nancy, 1850); Ad. Marcus, *Les Verreries du comté de Bitche: Essai historique (XVe-XVIIIe siècles)* (Nancy, 1887).

¹⁰ See, for example, A. de Girancourt, *Nouvelle étude sur la verrerie de Rouen et la fabrication du cristal à la façon de Venise aux XVIe et XVIIe siècles* (Rouen, 1886); H. Schuermans, *Verres fabriqués aux Pays-Bas (et en France) à la "façon de Venise" et "d'Altare"* (Letters published; Brussels, 1884-1893).

¹¹ Crystal ware made at Rouen was said to be equal in every respect to that blown at Murano—the Venetian suburb where the furnaces were actually located (Le Vaillant de la Fieffe, *Les Verreries de la Normandie, les gentilshommes et artistes verriers normands* [Rouen, 1873], 291); and Nevers was long known to travelers as the little French "Murano" (Schuermans, 107, 747).

¹² Quoted in Jules Houdoy, *Verreries à la façon de Venise: la fabrication flamande d'après des documents inédits* (Paris, 1873), 13-14. Mézières was a French shop.

II

Such, in brief, was the state of technology in the French glass industry when Louis XIV ascended the throne in 1643. During the following hundred years technological changes profoundly affected certain branches of the industry. In 1665 Colbert succeeded in attracting to France a handful of Venetian glass makers, who were to help set up a plate glass and mirror shop.¹³ So anxious was he to add this industry to those which already engaged the time and resources of his countrymen that he promised the workers very high wages and protection against the Draconian legislation of the Venetian Republic.¹⁴ The shop was first set up in Saint-Antoine, a Parisian suburb; but after 1667 the furnaces were moved to Tourlaville in Normandy, and the workshop at Saint-Antoine was converted into a grinding and polishing plant.¹⁵ Plate glass, no matter how it was made, had to be carefully finished if it was to be silvered for mirrors; consequently, its production required a much more extensive plant than was necessary for windowpanes or other objects not usually ground or polished. In accordance with Venetian methods, plate glass was blown in much the same manner as German windowpanes; *i.e.*, into long cylinders which were slit and then flattened out.

France made her most important contribution to the general technology of glass production when she successfully substituted for these old methods the process of casting or rolling plate glass. Squares of glass cast could be larger and thicker than those blown, and the adoption of the new technique led to large-scale, capitalistic production.¹⁶ A square foot of plate glass, furthermore, could now be made much more cheaply than had formerly been possible because the new method reduced the time

¹³ See Augustin Cochin, *La manufacture des glaces de Saint-Gobain de 1665 à 1865* (Paris, 1865) and Elphège Frémy, *Histoire de la manufacture royale des glaces de France au XVII^e et au XVIII^e siècle* (Paris, 1909).

¹⁴ In accordance with the prevailing commercial policy of European nations, Venetian laws imposed the death penalty on all artisans who deserted their native land in order to propagate the secrets of plate-glass manufacture in foreign countries, and created emissary executioners to trail the "traitors" and mete out justice by poison or dagger upon the first occasion.

¹⁵ Archives Nationales, G7. 216; Bibliothèque Nationale, Mélange Colbert, Ms. 142, fols. 277-280; Eugène Boivin, *Autour de la glacerie de Tourlaville* (Cherbourg, 1929), 77-85, 97 ff.; Frémy, 56 ff.; Archives de la Compagnie de Saint-Gobain, Vieilles archives. Unfortunately, most of the manuscripts in the private archives of the Saint-Gobain Plate Glass and Chemical Company (in the home office at Paris) are unclassified and grouped in eight *liasses* and two *cartons*. I was not allowed to number them, and the individual documents had no title. Consequently, all of my references to these important manuscripts are necessarily vague and incomplete.

¹⁶ See below, 157-158, 164-165.

required to make it by at least one half¹⁷ and because relatively unskilled and low-paid workers could be substituted for those highly skilled glass blowers who had formerly been indispensable. Nine master blowers working in the plate-glass factory at Tournlaville in 1701 received annual salaries ranging from 600 *livres* to 1,200 *livres*; in 1698 the operatives employed in the casting room at Saint-Gobain were paid wages varying from 288 *livres* to 480 *livres* a year. Furthermore, according to an official of the Royal Plate Glass Company, about one-third more men were required to blow a fixed amount of plate glass than to cast it.¹⁸

Five different Frenchmen¹⁹ have claimed the honor of inventing the casting process. Research among reliable primary and secondary data, however, suggests that Bernard Perrot, of Orléans, was the first to use this technique; he had successfully cast crystal in his shop shortly before April 2, 1687.²⁰ Be this as it may, on December 4, 1688, Louis XIV gave Abraham Thévart exclusive right throughout all France to cast glass in a factory which he and others were planning to build.²¹ His furnaces, first constructed at Saint-Germain-des-Prés near Paris,²² were located after 1692 at Saint-Gobain in Picardy.²³

The actual technique was so simple that one is puzzled—as one frequently is after a technological change is effected—why Venetian or other glass workers had not perfected it long before 1688. With the aid of a wheeled grappler and derrick the melted glass was taken from the furnace in buckets and poured on the smooth top of the casting table. Here it was spread out with a large copper roller. At least one of the tables used at Saint-Gobain before 1750 was 116 inches long, 70 inches

¹⁷ This estimate is based upon production-capacity figures for typical furnaces used in casting and in blowing (Archives de la Compagnie de Saint-Gobain, *Historique de la verrerie*, 167 ff., 178-179, 337, 341, 345, 389, 403 ff. 581; Vieilles archives, *liasses* and *cartons*; *Organisation de Saint-Gobain en 1769*: [III] *Administration*; *Portefeuille des arrêts et mémoires*).

¹⁸ Archives de la Compagnie de Saint-Gobain, Vieilles archives.

¹⁹ Bernard Perrot of Orléans, Pierre Perreau of Paris, Sieur Fresny de Rivières, Louis Lucas de Nêhou, and Abraham Thévart.

²⁰ Archives Départementales du Loiret, A. 396. Considerable uncertainty exists as to the actual date of the discovery, and M. Schuermans (804) certainly antedates it (*see* Boivin, 277 ff.).

²¹ Archives Nationales, F¹². 640, 1491; Archives de la Compagnie de Saint-Gobain, Vieilles archives, *liasse* 1665-1737; Bibliothèque Nationale, Fonds français, Ms. 21808, fols. 70-72. Whether Perrot had sufficient capital to utilize his invention apparently did not influence in the least the king's decision, for in none of the documents pertaining to this matter was this question considered.

²² Abraham du Pradel, *Le Livre commode des adresses de Paris pour 1692* (Edouard Fournier, ed.; Paris, 1878), II, 140-141.

²³ Archives de la Compagnie de Saint-Gobain, Vieilles archives; Frémy, 86.

wide, and $3\frac{2}{3}$ inches thick. Between nine and eleven tons of copper were used in making such a table, and roughly $2\frac{3}{4}$ tons were required for the smaller ones used at Saint-Gobain during the first quarter of the eighteenth century.²⁴ The smaller tables cost approximately 750 l. each. The instruments directly used in casting were considerably more expensive, therefore, than the pipes used in blowing.²⁵ Casting factories, furthermore, had to have much larger melting furnaces and annealing ovens than any workshops in which glass was blown. In 1702 the physical equipment at Saint-Gobain, where plate glass was both cast and blown, was valued at 322,903 l., whereas at Tourlerville, where plate glass was only blown, the plant was worth only 81,429 l.²⁶ Consequently, casting could hardly prove a profitable technique unless the output of glass was fairly large.

III

Almost as great an innovation as casting was the new process used in making bottles. But this time the French were borrowers and imitators rather than inventors. Some bottle manufacturers began about 1700²⁷ to copy English glass makers who had begun almost a century earlier²⁸ to burn coal in their furnaces in place of wood. Throughout the seventeenth century most bottles blown in French shops had been extremely fragile and unfit for bottling effervescent beverages.²⁹ This situation was remedied after 1700 as increasing numbers of French entrepreneurs began to make bottles while burning only coal.³⁰ Their glass, popularly de-

²⁴ Archives de la Compagnie de Saint-Gobain, *Lettres . . . mémoires techniques sur les glaces, 1769-1800*.

²⁵ In 1700 all instruments directly used in casting at Saint-Gobain were valued at 14,558 l. (Frémy, 267-268 n.).

²⁶ Archives de la Compagnie de Saint-Gobain, *Vieilles archives, liasses and cartons*. Each of these establishments seems to have had two main furnaces. One at Saint-Gobain was for casting; the other was used in blowing.

²⁷ Sometime between 1669 and 1700 bottles were made after English methods in a factory at Charleroi. Louis XIV had chartered this factory in 1669, but Charleroi had probably reverted to Spanish rule before the shop adopted the English techniques. (Archives Nationales, AD^{x1}. 53; F¹². *registres* 71², pp. 118-120; 73, pp. 561-565; *liasse* 1488A; K. 1032, document 73.) Gaspard Thevenot, shortly after 1708, built a bottle factory near the castle of Folembray in Picardy (Archives Nationales, F¹². 1488A; G⁷. 1697). So far as I have been able to ascertain, this factory was the first shop in France proper which made bottles in the English manner.

²⁸ John U. Nef, *The Rise of the British Coal Industry* (London, 1932), I, 219.

²⁹ Haudicquer de Blancourt, I, 36-37.

³⁰ In 1740 there may have been in France proper as many as fourteen bottle factories using only coal in their melting furnaces. This estimate is based on numerous manuscripts in various departmental and national archives and the specific references—totaling more than 75—can be obtained from my unpublished dissertation entitled "The History of the French Glass Industry from 1640-1740 (The University of Chicago, 1940), 25-26.

scribed as *à la façon d'Angleterre*, was invariably coarse, darkly colored, and not very breakable. These new bottles were stronger than the others because the average temperature in the melting furnaces was considerably increased after bottle producers substituted coal for wood. The melting process was therefore speeded up, and more sand and less potash or soda could be used in the batch.

It was not easy to burn coal in place of wood. At least three obstacles stood in the way: (1) most furnaces burning wood were not equipped with drafts strong enough to whip up as hot a blaze from mineral fuel as was required to melt batch;³¹ (2) the obnoxious fumes from coal smoke hampered the blowers as they worked before the furnace doors; and (3) the smoke colored the glass lying exposed to the fire in open crucibles. If the first of these obstacles was to be overcome, a special furnace, copied after the English, had to be built. Outwardly, it resembled the German furnace,³² which various French shops manufacturing white or green glass had long been using. It was square or rectangular at its base and had a fire grate, open at both ends, extending from one end of the furnace to the other. Its special feature lay in its distinctive underground structure. A long, small tunnel or cave was built underneath the furnace, cutting the ash bin at right angles and extending beyond the walls of the workshop in which the furnace was housed. This supplied a very strong draft, for the cooler air outside the shop raced through the tunnel into the hot furnace. Apparently without exception, all coal-burning furnaces built in France after 1700 were modeled along these lines. The owners of the Sèvres bottle factory stated around 1747 that such a furnace had recently cost them 8,000 *l*.³³ This was probably twice the cost of building an entire shop similar to the ones in Southern France which had been producing bottles and various objects of common glass for centuries.³⁴

The English-type furnace in itself did not lessen the inconvenience that the sulphurous coal fumes caused glass blowers. The workshop that was typical of all branches in the French glass industry, and that housed the melting furnaces and annealing ovens was square or rectangular and equipped with numerous doors and windows through which smoke from its furnaces passed. Few had any chimneys. When glass was being melted,

³¹ See above, 154.

³² Archives Nationales, F¹². registre 75, p. 585; *Encyclopédie méthodique: arts et métiers mécaniques*, VIII, 454.

³³ Archives Nationales, V⁷. 491.

³⁴ See below, 164.

an uninformed passerby probably thought that the shop was on fire. The glass shop *à l'anglaise*, on the other hand, resembled a large inverted funnel. Its floor plan was circular; and after rising above ground for some eight or ten feet, its walls converged and formed a single high chimney, the base of which was eighteen or more feet above the tiebeams. All the windows and doors of the shop were closed while glass was being melted, and a direct current of air was established *throughout the entire building*. The only way air could enter was through the tunneled drafts of the furnace, and its only outlet was the chimney in the roof of the shop. The English shop, consequently, had two great advantages over the French: Coal fumes were quickly drawn from the interior of the workroom, and a higher temperature could be attained in the melting furnace because of the stronger draft. This latter advantage, it was said, was especially important because the time required to liquefy the batch was reduced by two thirds, and one-fifth less coal had to be burned.³⁵

Despite its distinct advantages, the French were slow in copying the English shop. As late as 1784 an enterprising man named De Revelard addressed a memoir to the French Government in which he claimed to have acquired the "secret" of constructing glass shops in the English manner. He, therefore, asked the Government for financial assistance so that he could build one in Provence which would serve as a model to other glass producers.³⁶ De Revelard was correct in stating in his petition that no faithful copy of the English model had been built in France, yet several Frenchmen making dark bottles had erected shops which embodied many English features. Before the middle of the eighteenth century, the workshop of a bottle factory at Bordeaux, for example, had been built with a steeply slanting roof, pierced in the center by a large opening through which smoke could escape. The base of the building, however, was rectangular instead of circular.³⁷

The third difficulty encountered when coal was substituted for wood, namely, keeping the coal smoke from coloring the glass in the open crucibles, was not at all successfully solved by glass makers in France before 1740.³⁸ Certain entrepreneurs making crystal glass were trying as late as 1786 to overcome this difficulty by using coke, but their results were

³⁵ *Encyclopédie méthodique: arts et métiers mécaniques*, VIII, 468-469.

³⁶ Archives Départementales des Bouches-du-Rhône, C. 3418.

³⁷ Archives Départementales de la Gironde, C. 310, 1594.

³⁸ Archives Nationales, F¹². 1487, 1489A; Archives Départementales de la Seine-Inférieure, C. 159.

not encouraging.³⁹ M. Deslandes, one-time director of the Saint-Gobain plate-glass factory before the French Revolution, made some rather scornful remarks concerning coke when he was discussing different types of fuel that could be used by glass makers. "I shall not even mention *charbon dessouffré*," he wrote, "which people have talked about so much and which has been formerly praised all too highly and without reason."⁴⁰ By 1612 an enterprising Englishman had solved the problem by constructing covered crucibles which kept the fire and smoke from coming in contact with the glass,⁴¹ but for some reason or other covered crucibles were not used in French shops before 1740 or to any great extent thereafter until the Revolution. This is proved by the remarks of the author of an article on the art of glass making found in the *Encyclopédie méthodique: arts et métiers mécaniques*.⁴² In 1791 he wrote:

The most beautiful drinking cups à la *Bohême* that are known today, such as those of Saint-Quirin, Saint-Louis, etc., are made in furnaces heated with wood. Coal-burning furnaces have been experimented with, but no matter what care, skill, or intelligence is given to the experiment the color of the glass is never as bright and clear as that melted in log-burning ovens. The smoke from the fuel is a sufficient cause of this defect. . . . One cannot hope to attain the same perfection in glass making with a coal fire that one does with a wood fire *unless one succeeds in using covered crucibles in the melting process*.⁴³

The failure to use covered crucibles explains why only bottle manufacturers in France were able to substitute coal for wood. Whether bottles were dark brown or white mattered little. In fact, wine and brandy merchants during the eighteenth century came to accept only the darkest bottles, for this very darkness was taken as an indication of the superior strength of the bottles.⁴⁴ Several documents indicate that various producers of crystal glass had tried to use turf or some sort of mineral fuel in place of wood in 1600,⁴⁵ 1616-1619,⁴⁶ and 1666;⁴⁷ but apparently none

³⁹ Archives Nationales, F¹². 2425.

⁴⁰ Archives de la Compagnie de Saint-Gobain, *Historique de la verrerie*, 28.

⁴¹ John U. Nef, "A Comparison of Industrial Growth in France and England from 1540 to 1640," *The Journal of Political Economy*, XLIV (1936), 306.

⁴² VIII, 486-487.

⁴³ Italics supplied.

⁴⁴ Archives Départementales de la Seine-Inférieure, E. 785.

⁴⁵ Archives Nationales, X^{1a}. registre 8644, fols. 167-169.

⁴⁶ Le Vaillant de la Fieffe, 278.

⁴⁷ Paul-M. Bondoïs, *Les Verreries nivernaises et orléanaises au XVII^e siècle: Jean Castellan et Bernard Perrot (1647-1709)* (Paris, 1932), 9-10; Edouard Garnier, *Histoire de la verrerie et de l'émaillerie* (Tours, 1886), 169.

of these experiments had been very successful, for they left no lasting imprint on the development of the industry in France. A glass worker of German origin could truthfully state in 1724 that there was not a single coal-burning furnace in all of France in which crystal glass was made.⁴⁸ Norman producers of windowpanes seem to have never burned anything but wood in their furnace before 1789. There is some evidence, on the other hand, that window glass made in the German manner may have been melted in coal-burning furnaces located at Fresnes around 1716⁴⁹ and at Brassac in Auvergne in 1740.⁵⁰ During the latter half of the eighteenth century several shops, especially around Lyons, made large quantities of such glass while burning only coal.⁵¹ The Royal Plate Glass Company, which had a nationwide monopoly in the production of plate glass and mirrors, used wood almost exclusively from 1665 to 1789.⁵²

The French were even slower in adopting the English techniques of making flint glass than they were in substituting coal for logs. In fact, no French shop successfully produced brilliant crystal made with lead oxide until 1786.⁵³ A government official reported in December 1786: "To tell the truth, several French shops make a white glass which is beautiful enough and to which is given the name 'crystal,' but none of it has the beauty and weight of real crystal, i.e., of England; and I think that, in general, French crystal does not enjoy a great reputation, and that little is exported to foreign countries."⁵⁴ "Italian" crystal blown in France during the eighteenth century was not nearly so popular or so artistically wrought as that made during the sixteenth and first half of

⁴⁸ Archives Départementales de la Gironde, C. 1594.

⁴⁹ Archives Nationales, F¹². 1488A.

⁵⁰ Archives Départementales du Puy-de-Dôme, C. 574.

⁵¹ Archives Départementales de la Gironde, C. 1596; Archives Départementales du Rhône, C. 13.

⁵² Some attempts were made to burn coal in its furnaces at Tourlaville and Saint-Gobain, but the experiments were never wholly satisfactory or popular (Archives Nationales, F¹². 1487; O¹. 1992A, *côtes* 4 and 9; Archives de la Compagnie de Saint-Gobain, Vieilles archives, *liasses* and *cartons*; *Historique de la verrerie*, 20, 21; Bibliothèque Municipale de Caen, Ms. 425, Vol. I, A. 2, p. 3; Cochin, 76; Frémy, 253).

⁵³ At this time a French factory was successfully melting this kind of crystal. This was the large Cristallerie de la Reine, which had been moved to Montcenis in Burgundy soon after it had first been opened at Saint-Cloud (Archives Nationales, F¹². 1486, 2425). At least seven other attempts to make flint glass were made either shortly before or after 1786 (Archives Nationales, F¹². 1486, 1487, 1497B, 2425, 2766; Archives Départementales de l'Hérault, C. 2766; Archives Départementales de la Seine-Inférieure, C. 159, 2120).

⁵⁴ Archives Nationales, F¹². 1486.

the seventeenth century.⁵⁵ The best "crystal" produced by Frenchmen around 1740 was made according to German or Bohemian methods.⁵⁶ The number of French shops using these methods and the German-type furnace multiplied after 1700 and supplied a larger and larger portion of the growing domestic demand for windowpanes and other objects made of white glass.

IV

So far this study has revealed that most branches of the French glass industry were affected by important technological changes. Frenchmen first acquired the knowledge and skill of making plate glass soon after 1665 by watching immigrant Venetians, and later they revolutionized the industry by developing the casting process. Producers successfully burned coal in bottle furnaces; and German techniques and furnaces, although not unknown in Northeastern France before 1640, became increasingly popular with entrepreneurs making white and window glass in other provinces. These technological improvements—important in themselves to historians generally—are especially significant from an economist's viewpoint since they directly influenced the size of individual shops and their scale of operations.

By 1740 several shops making plate, bottle, window, and white glass had acquired physical plants which were impressive. In addition to the central hall in which glass was melted and blown there were usually several storehouses for raw materials and finished glassware; workshops for the blacksmith, carpenter, cartwright, forger, potter, and crate- and brick-makers; stables for draft animals; and barracks in which the workers lived.⁵⁷ Many factories in the northern half of France resembled small villages.⁵⁸ The premises of the plate-glass factories at Tournellville and Saint-Gobain were entirely surrounded by walls, and all gates were care-

⁵⁵ Savary des Bruslons, during the first quarter of the eighteenth century, stated in his *Dictionnaire universel de commerce* (I, col. 1617; II, col. 1893): "Any kind of drinking cup other than ordinary glass is scarcely used any more in France, and Venetian crystal glasses are no longer esteemed. . . ." "Frenchmen scarcely know at present what Venetian Goblets are like."

⁵⁶ Henri Havard, *Les Arts de l'ameublement: La verrerie* (Paris, n.d.), 196. Attempts were even made to introduce Bohemian, German, and Lorraine techniques into Italy (Schuermans, 292, 549, 874).

⁵⁷ By the middle of the eighteenth century the Royal Plate Glass Company had built 52 houses for its workers at Saint-Gobain, and shortly after 1770 it built 22 more (Archives de la Compagnie de Saint-Gobain, *Organisation de Saint-Gobain en 1769: [III] Administration*).

⁵⁸ Archives Nationales, Q¹. 804; Archives Départementales de la Seine-Inférieure, E. Famille du Vaillant Desmarêts; Archives de la Compagnie de Saint-Gobain, *Historique de la verrerie*, 217; Boivin, 127; Baron de Dietrich, *Description des gîtes de minéral, forges, salines, verreries . . . de la Lorraine méridionale et septentrionale* (Paris, an VIII), 325; Frémy, 190; Le Vaillant de la Fieffe, 134-135.

fully watched, presumably to prevent the theft of industrial secrets. In 1753, the Intendant of Finances accused the officials at Tourlaville of giving refuge to an escaped prisoner,⁵⁹ and on other occasions Crown officials referred to such factories as veritable fortresses into which not even the agents of the salt monopoly could penetrate to prevent fraud.

All this indicates that some producers had invested considerable amounts of capital in physical equipment. The buildings and land of a plate-glass factory at Dombes were valued in 1709 at 79,912 *l.* and its tools and equipment at 29,276 *l.*⁶⁰ The Royal Plate Glass Company⁶¹ had buildings, land, and equipment at Saint-Gobain, Saint-Antoine, and Tourlaville the total value of which in 1702 was almost 550,000 *l.*⁶² The physical equipment of the coal-burning bottle factory at Saint-Paul near Rouen was given a value of 32,264 *l.* 7*s.* 2*d.* in its balance sheet prepared on August 10, 1735,⁶³ and there were several bottle factories considerably larger than this one. The little glass shops (*petites verreries*) in which common and even some crystal glass was made, on the other hand, were much smaller. The techniques they employed did not require any extensive plant or expensive equipment. Even as late as the middle of the eighteenth century only from three to five thousand *livres* was necessary to build and equip such a shop.⁶⁴

These figures as to the amount of capital invested in physical plant indicate that plate-glass and bottle-glass factories operated on a much larger scale than did those making crystal and common green glass. This generalization, furthermore, is supported by additional data on various shops which give the value of their total assets, the number of workers they employed, and the amount of glassware they produced each year.

The Royal Plate Glass Company, when it was first organized in 1665, was capitalized at 60,000 *livres tournois*. By May 1702 its assets were valued at almost four million; and from this date to 1778 they more than trebled in value. During the decade 1741-1750 the company employed from 900 to 1,000 workers on either a part-time or full-time

⁵⁹ Archives Départementales du Calvados, C. 2973, 2975.

⁶⁰ Archives Nationales, G⁷. 1690. If these sums had been spent to employ unskilled laborers, approximately 272,970 men could have been put to work for one day.

⁶¹ This company was both privately owned and operated. In 1695 the glass-blowing factory with furnaces at Tourlaville and finishing plant at Saint-Antoine had merged with the glass-casting factory established at Saint-Gobain.

⁶² Archives de la Compagnie de Saint-Gobain, Vieilles archives, *liasses* and *cartons*.

⁶³ Archives Départementales de la Seine-Inférieure, E. 785.

⁶⁴ Archives Départementales de l'Hérault, C. 2764; Archives Départementales de la Nièvre, B. 230; Paul Rodier, *Les Verreries des hautes forêts de Darney* (Epinal, 1909), 32.

basis and may have made as much as 850 tons of glass each year. By 1740 the company was selling annually glass worth almost a million *livres*.⁶⁵

The largest of the dark-bottle factories built in France after 1700—the one located at Sèvres—represented a capital investment of more than 200,000 *l.* and made about 340 tons of bottles each year from 1737 through 1739. The others were somewhat smaller. Their annual output, which ranged from 160 to 240 tons of dark glass, was produced by 25 or 35 artisans working with equipment valued anywhere from 60,000 *l.* to 120,000 *l.*⁶⁶

Although most of the Norman factories producing window glass in 1740 had been in existence for over a century, they were no larger than the dark-bottle factories; nor had they increased their scale of operations to any great extent since 1640. In 1740 the value of their assets ranged from 50,000 *l.* to 100,000 *l.*, and the 30 or 50 artisans working in each plant produced each year from 150 to 200 tons of window glass and about 70 tons of common green glass.⁶⁷

The shops for making windowpanes in the German or Bohemian manner, which were built in Northeastern France after 1700, were usually smaller than the window-glass factories in Normandy. Probably none of them produced more than 150 tons of glass in any year preceding 1740 even though they hired almost as many workers as the Norman fac-

⁶⁵ This summary is based on data found in: Archives Nationales, E. *registre* 1911 (9 mars 1700); F¹². 1490, 1491; G⁷. 219 (8 septembre 1714), 1690; O¹. 1992A, *côtes* 2 and 4; T. 14¹, *côte* 10; Archives Départementales du Calvados, C. 2975; Archives de la Compagnie de Saint-Gobain, Vieilles archives, *liasses* and *cartons*; *Délibérations*, fol. 47; *Etat des officiers et commis, 1774-1792*; *Historique de la verrerie*, 126 ff., 167 ff., 178-179, 337, 341, 345, 389, 403 ff., 581; *Organisation de Saint-Gobain en 1769: (I) Fabrication, (II) Ouvriers, (III) Administration; Portefeuille des arrêts et mémoires*; Bibliothèque Nationale, Collection Moreau, Ms. 1384, fols. 240-249; Mélange Colbert, Ms. 142, fol. 277; Frémy, 57-58, 59, 60, 103, 105, 218 ff., 233, 237 n. 1.

⁶⁶ Archives Nationales, E. *registre* 1035B, fols. 133-134; F¹². *registres* 75, pp. 577 ff.; 83, pp. 456-475; *liasses* 1486, 1488A, 1489A, 1489B, 1490; Q¹. 1508 (28 octobre 1754); V⁷. 490; Archives Départementales du Calvados, C. 2975; Archives Départementales de la Côte-d'Or, C. 1918; Archives Départementales de la Gironde, C. 1594, 1595; Archives Départementales de l'Hérault, A. 45, document 107; Archives Départementales d'Ille-et-Vilaine, C. 1518, 3929; Archives Départementales d'Indre-et-Loire, C. 140; Archives Départementales du Puy-de-Dôme, C. 576; Archives Départementales du Rhône, C. 13, 14; Archives Départementales de la Seine-Inférieure, E. 785.

⁶⁷ Archives Nationales, F¹². 1486, 1489A; G⁷. 726; Y. 14124; Archives Départementales du Calvados, C. *registres* 22-25, p. 752; Archives Départementales de la Seine-Inférieure, E. Famille du Vaillant Desmarêts; Archives Départementales du Tarn, E. *registre* 329, fols. 247-248; Archives de la Compagnie de Saint-Gobain, Vieilles archives, *liasse* 1665-1737; Le Vaillant de la Fieffe, 19, 147-148, 170, 203, 481.

tories.⁶⁸ It is interesting to note at this point, however, that these plants were on the verge of increasing their size. During the latter half of the eighteenth century several of them—notably, Saint-Louis and Saint-Quirin—operated on a scale at least twice as large as that of any similar plant in 1740.⁶⁹

Common and white glass in 1640 had been made almost entirely in small establishments; and, in spite of a few exceptional cases, production on a small scale continued to characterize these branches of the industry a hundred years later. The majority of the common glass shops scattered about in the forests of Guyenne, Languedoc, Lorraine, and Provence had certainly not increased their output appreciably since 1640,⁷⁰ and were probably producing from 30 to 70 tons of glass during each of the years immediately preceding 1740.⁷¹ At the same time, however, there were a few factories making common green bottles the annual output of which may well have been 160 or 200 tons, and a few others specializing in goblets and drinking cups with a probable output of 150 tons each year. Many of these larger factories were located in Northeastern France, a region where prosperity in the industry became especially noticeable soon after 1720.

V

Certain conclusions can now be drawn from this survey: (1) the largest operating plant in the entire glass industry was to be found in that branch making plate glass and mirrors; (2) whereas in 1640 most French bottles had been made in small shops equipped with log-burning furnaces, a hundred years later large-scale production was characteristic of all the bottle factories using coal and of several of the others still burning wood; (3) window-glass shops in Normandy had already become fairly large by 1640, and there was no marked tendency for the typical shop in this field to expand its output before 1740; (4) enterprises

⁶⁸ Bibliothèque Nationale, Collection Moreau, Ms. 901, fol. 657; Baron de Dietrich, 26, 34, 37, 301, 345, 374, 378; *Description des gîtes de minéral, forges, salines, verreries . . . de la Haute et Basse-Alsace* (Paris, 1789), 261, 330, 357, "Tableau général" in the Appendix; A. Fournier, *La Verrerie de Portieux* (Nancy, 1886), 14-15 n., 34, 75 n. 1.

⁶⁹ Archives Nationales, F¹². 680, 1487; Q¹. 805.

⁷⁰ In fact, it seems more likely that they were producing less in 1740 than a century earlier.

⁷¹ Archives Nationales, E. 1741 (18 février 1667); F¹². 680, 1488A; Q¹. 1625, 1626; Archives Départementales des Bouches-du-Rhône, C. 2301; Archives Départementales du Calvados, C. 2975; Archives Départementales de l'Hérault, C. 2760; Archives Départementales de la Nièvre, E. registres 265, 266; Bibliothèque Nationale, Collection Moreau, Mss. 901, fol. 678; 977, fol. 152; Le Vaillant de la Fieffe, 369, 389; Saint-Quirin, "Les Verriers du Languedoc (1290-1790)," *Bull. de la soc. languedocienne de géographie*, XXVII (1904), 288; XXVIII (1905), 201-203, 355-358.

making window and white glass according to German or Bohemian methods in 1740 were considerably larger than most seventeenth-century white glass shops; (5) the small shop still dominated the common glass industry.

These conclusions indicate that large-scale production was far more common in the glass industry as a whole in 1740 than it had been a century earlier. In many regions, especially in the southern provinces, the number of small shops producing common glass and Venetian crystal had decreased, and shops with an annual output of more than one hundred fifty tons had definitely increased in number. In 1700 there had not been a single establishment in France making dark bottles in the English manner; forty years later the country had fourteen. Plate glass, furthermore, had not been produced in commercial quantities in French shops until 1665; by 1740 the Royal Plate Glass Company had probably become the largest factory of its kind in the world. At the same time the glass industry was again flourishing in Northeastern France. The sixteenth century had been an era of prosperity for this region, but during the seventeenth century all branches of the glass industry there had languished. From 1699 through 1740 at least twenty-four shops were reopened or built for the first time in the region comprising Alsace, County of Bitche, Franche-Comté, and Lorraine; and many of these, producing window and white glass after German or Bohemian methods, operated on a large scale.⁷²

These developments in the size and number of individual plants in the different branches of the glass industry were closely correlated with the technological progress achieved from 1640 to 1740. The new methods of making plate and bottle glass were conducive to large-scale production, and the increasing popularity of white and window glass made according to German techniques doubtless stimulated the expansion of the industry in Northeastern France. Technological forces, however, were not the only ones affecting the scale of operations of individual shops. The Royal Plate Glass Company probably would not have been as large as it was in 1740 had it not enjoyed exclusive privileges in the production of plate and mirror glass throughout the nation. Nor would the dark-bottle or German window-glass industries have prospered so much as they did after 1700 if the use of their products among the middle and lower classes in French society had not increased.

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⁷² These generalizations about the increase in the number of shops in the different branches of the glass industry from 1640 to 1740 are based on a study of both primary and secondary sources. Exact reference to these sources—all too numerous to indicate here—can be obtained from my unpublished University of Chicago dissertation.

